

# Permeable Reactive Barriers



**September 12, 2002**  
**NJDEP Public Hearing Room**  
**Sponsors: NJDEP & ITRC**



- 1:00 - 1:15      Welcome & ITRC Update**  
Brian Sogorka, NJDEP Remediation Technology Manager
- 1:15 - 3:45      Technical Program**  
Matthew Turner, NJDEP, Moderator
- 1:25 - 2:10      Overview of Granular Iron PRBs for VOC Treatment**  
Michael L. Duchene, M.A.Sc., P.Eng., EnviroMetal Technologies, Inc.
- 2:10 - 2:55      Injection of Zero Valence Iron Powder for Insitu Chemical Reaction**  
John J. Liskowitz, ARS Technologies, Inc.
- 2:55 - 3:40      Permeable Reactive Barriers Design and Installation**  
Paul Boyajian and Steve Brauner, Parsons
- 3:40 - 3:45 Wrap-up**



# Permeable Reactive Barriers



## Introduction:

**Brian Sogorka,**  
NJDEP Remediation  
Technology Manager





## **Regulatory Acceptance for New Solutions**

**Marybeth Brenner**  
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## **Purpose of ITRC**

ITRC is a state-led, national coalition of regulators and others working to

- \* improve state permitting processes and
- \* speed implementation of new environmental technologies.



## Goals

- \* Achieve better environmental protection through innovative technologies
- \* Reduce the technical/regulatory barriers to the use of new environmental technologies
- \* Build confidence about using new technologies

## Other Participants

- Industry representatives
- Host organization

- Academia

- Public stakeholders

- Federal agencies



U.S. Department of Energy



U.S. Environmental Protection Agency



U.S. Department of Defense



Environmental Council of the States

- State organizations



Western Governors' Association



Southern States Energy Board

## Products & Services

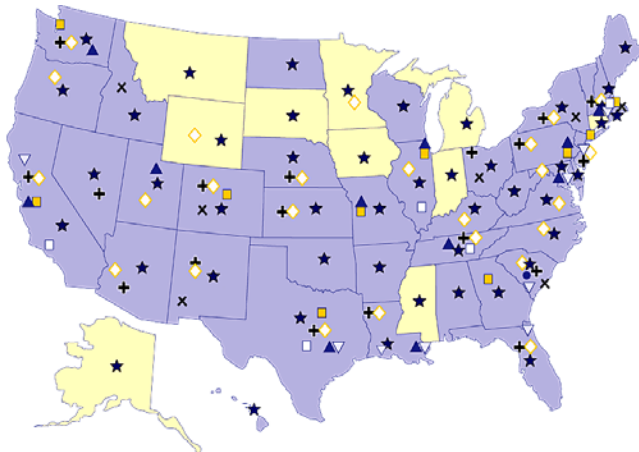
- \* Regulatory and Technical Guidelines
- \* Technology Overviews
- \* Case Studies
- \* Peer Exchange
- \* Technology Advocates
- \* Classroom Training Courses
- \* Internet-Based Training Sessions



## Active Technical Teams

- \* Alternative Landfill Technologies
- \* Brownfields
- \* Constructed Wetlands
- \* Contaminated Sediments
- \* Dense Nonaqueous Phase Liquids
- \* Diffusion Samplers
- \* DOE Gate 6 Technologies
- \* In Situ Bioremediation
- MTBE-Contaminated Groundwater
- Permeable Reactive Barriers
- Radionuclides
- Remedial Process Optimization
- Sampling, Characterization, and Monitoring
- Small Arms Firing Range
- Unexploded Ordnance

## Nationwide Success



March 2002

■ Active ITRC States (40 plus DC)

★ Students Trained

✦ Product Use at a Site

◇ Institutional Success

✕ ITRC Network Success

▲ Natural Attenuation Training Course

▽ Accelerated In Situ Bioremediation Training Course

■ Permeable Reactive Barriers Training Course

□ Phytotechnologies Training Course

● Unexploded Ordnance Training Course

## Contacts

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### Program Director:

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# Technical Program

Matthew Turner  
NJDEP, Moderator

**ITRC Permeable Reactive Barriers Team**  
Matthew Turner,  
**Site Remediation Program, NJDEP**

**Permeable Reactive Barriers for Groundwater Remediation**  
Paul Boyajian and Steve Brauner,  
**Parsons**

**Overview of Granular Iron PRBs for VOC Treatment**  
Michael L. Duchene, M.A.Sc., P.Eng.,  
**EnviroMetal Technologies, Inc.**

**Injection of Zero Valence Iron Powder for  
*In situ* Chemical Reaction**  
John J. Liskowitz,  
**ARS Technologies, Inc.**





## **ITRC**

### **Permeable Reactive Barriers Team**

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#### *Documents*

- 1) Regulatory Guidance for Permeable Reactive Barriers  
Designed to Remediate Chlorinated Solvents  
December 1999 (2nd Edition)*
- 2) Regulatory Guidance for Permeable Reactive Barriers  
Designed to Remediate Inorganic and Radionuclide  
Contamination  
September 1999*

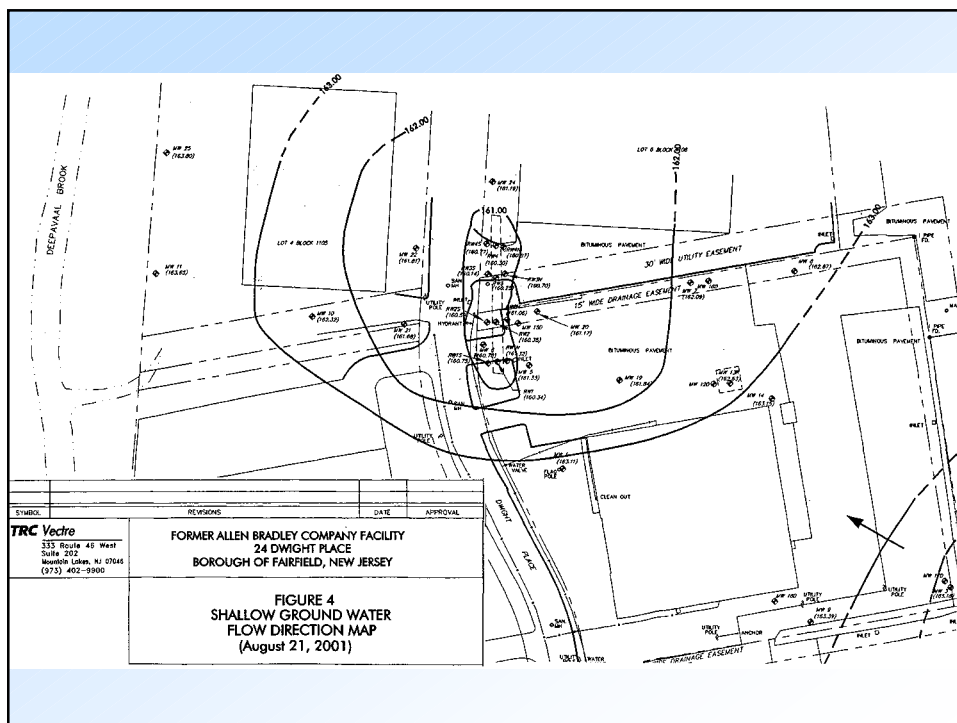
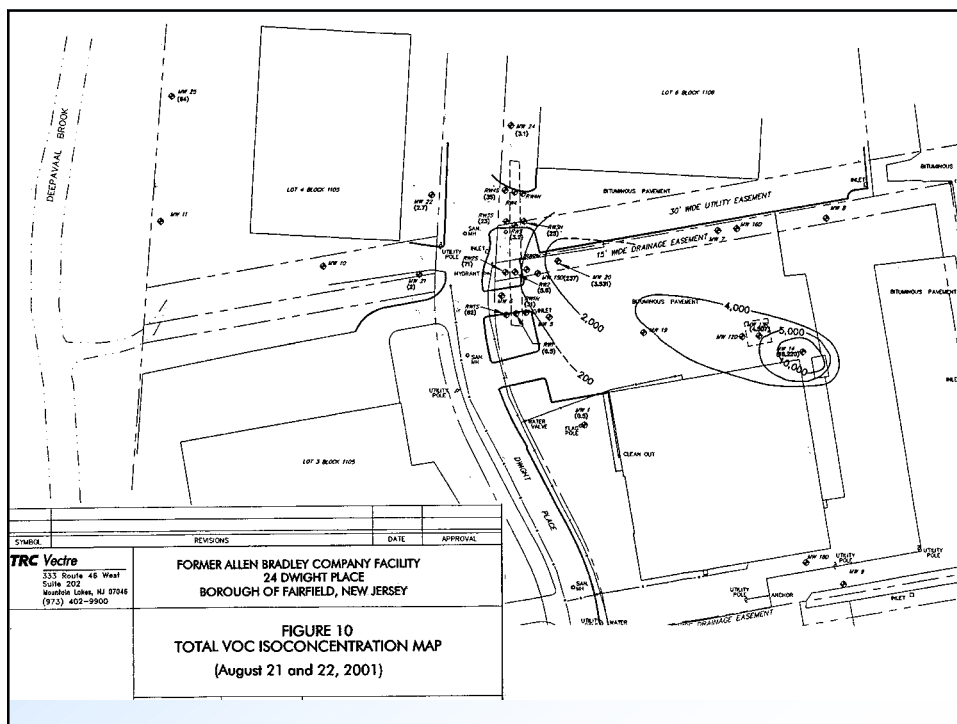
## **ITRC**

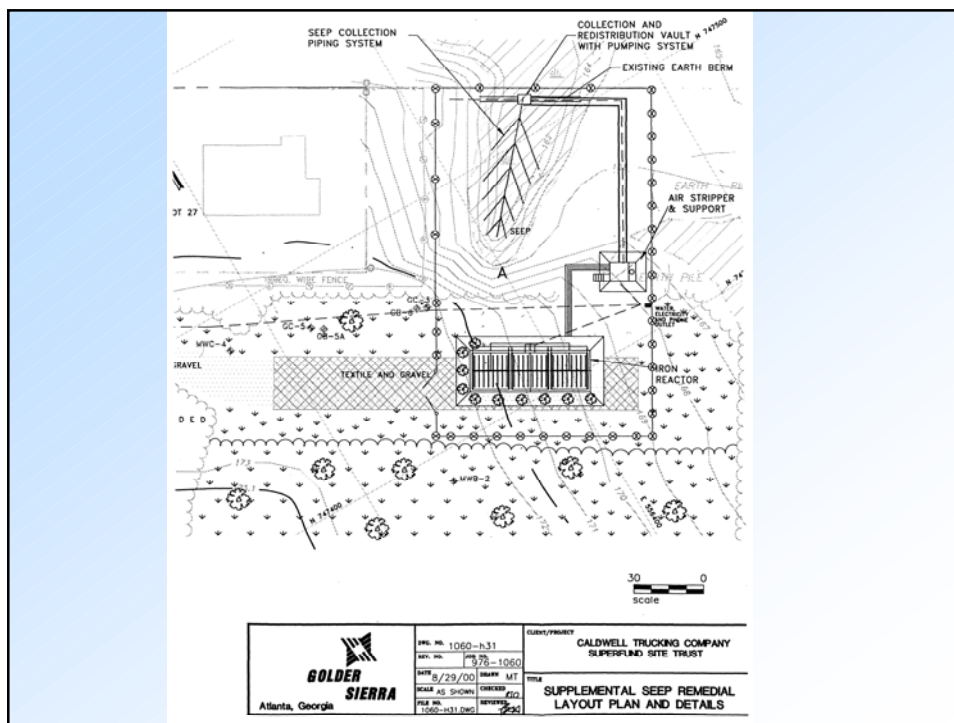
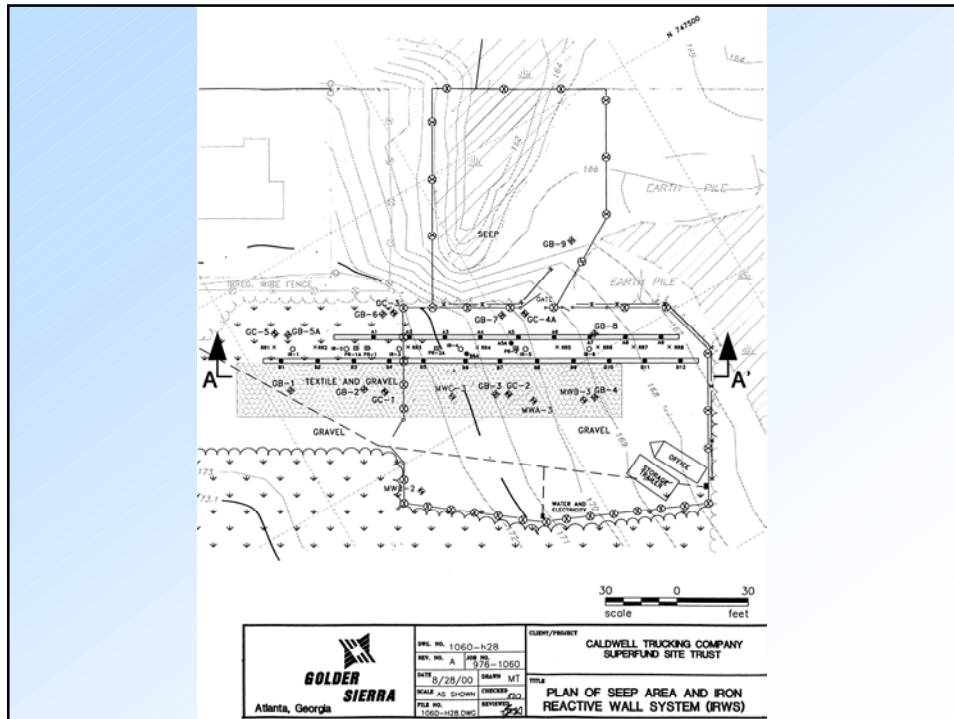
### **Permeable Reactive Barriers Team**

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#### *Documents*

- 3) Design Guidance for Application of Permeable Barriers for Groundwater Remediation  
March 2000*
- 4) Draft Report - Permeable Reactive Barrier Performance and Guidance  
April 25, 2002*





# *Permeable Reactive Barriers for Groundwater Remediation*



*Presented by*  
**Steve Brauner, Ph.D.**  
**Paul Boyajian, P.E.**  
PARSONS

*Presented to*  
**NJDEP SRP**  
September 12, 2002



## *Presentation Outline*

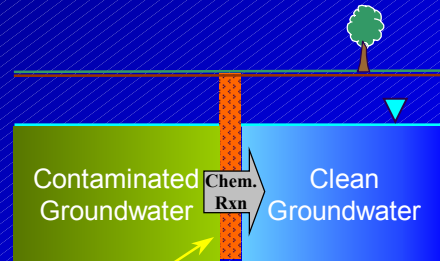
- ◆ Theory
- ◆ Pre-design investigation
- ◆ Remedial design
- ◆ Installation techniques
- ◆ Case study





## Theory

- ◆ 'Passive' approach
- ◆ Various classes of contaminants treated



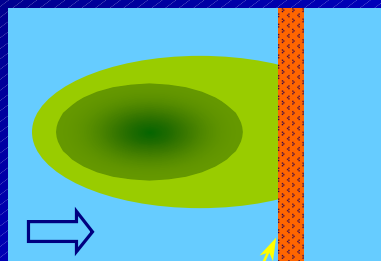
← Reactive Media  
(e.g. PRBs and injections)

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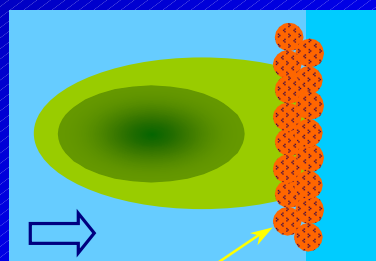


## PRB Configurations – Plan (1)

Continuous Barrier  
(Trenching)



Continuous Barrier  
(Injection)



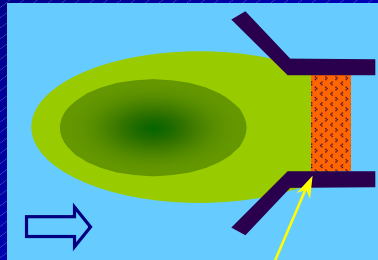
Reactive Media

Parsons

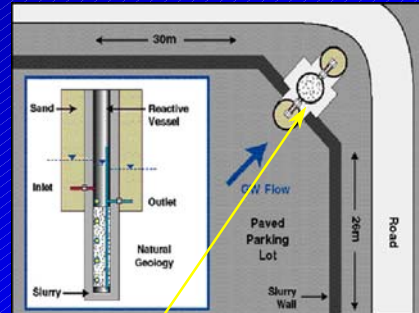


## PRB Configurations – Plan (2)

Funnel and Gate



Reactive Vessel



Schematic courtesy of ETI

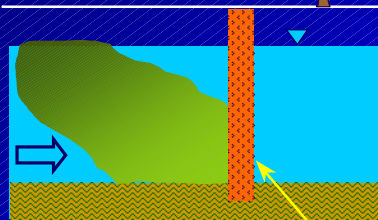
Reactive Media

Parsons

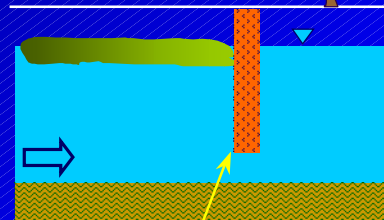


## PRB Configurations – Profile

Keyed



Hanging



'Key' material  
(e.g. clay, till, bedrock)

Reactive Media

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## *Reactive Media*

- ◆ Purpose: Alter or enhance local subsurface environment to favor contaminant removal
- ◆ Contaminant removal mechanisms
  - Abiotic degradation
  - Enhanced biodegradation
  - Precipitation
  - Sorption
- ◆ Some materials/processes are patented

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## *Reactive Media*

	Reactive Iron	Organic Carbon	GAC	O <sub>2</sub> Delivery	Zeolites
CAHs	→	→	→	→	
Metals Cr(VI), As, Cu, Ni	→	→			→
Acid Mine Drainage		→			
PHCs			→	→	
Nitrate		→			

Parsons



## *Pre-design Investigation*

### ◆ Purpose:

- Identify potential backfill materials;
- Perform treatability testing, as needed;
- Obtain subsurface information for design and construction purposes;
- Estimate local groundwater velocity; and
- Identify subsurface anomalies.

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## *Pre-design Field Investigation*



### ◆ Geologic

- Hydraulic conductivity
- Soil properties
- Key material
- Excavation effort
- Boring spacing
- Blow counts

### ◆ Geochemical

- Contaminants of concern
- Redox condition
- “Inhibitor” compounds

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## Pre-design Lab Testing



Photo courtesy of ETI

- ◆ **Treatability Testing**
  - Bench-scale
  - Rate of contaminant removal
  - Compare various media types/combinations
  - Particularly important when “inhibitor compounds” are present
- ◆ **Biopolymer slurry compatibility**
  - Estimate ‘in-trench’ stability time via viscosity measurements
  - Evaluate various biopolymers
  - Necessity of additives

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## Design Considerations

<i>Critical Questions</i>	<i>Controlling Factors</i>	<i>Design Criteria</i>
1. Treatment capacity	Contaminant mass	Reactive media mass
2. Residence time	Rate of reaction; Local groundwater velocity	PRB thickness
3. PRB alignment & installation technique	Buildings/Utilities; Soil conditions; Contaminant depth	Selection of reactive media delivery technique
4. PRB longevity	Mineral precipitation; Loss of reactivity	Sand addition; Bench-scale testing

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## *Primary Design Documents*

- ◆ Alignment drawing(s)
- ◆ Cross-section drawing(s)
- ◆ Monitoring locations
- ◆ Technical specifications

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## *Installation Techniques*

- ◆ Trenching
  - Traditional (open) trenching to water table depth
  - Continuous trenching to 25' feet below land surface
    - Custom-built machinery that excavates and places backfill in single 'pass'
  - Biopolymer slurry trenching to 100' feet below land surface or more
    - Provides temporary support during excavation, allowing trench to be backfilled with a material of choice
- ◆ Injections
  - Pneumatic
  - Liquid

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## *Continuous Trenching*



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## *Slurry Trenching*



Excavation in the “dry”  
can lead to failure, so...

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## Slurry Trenching



... use a slurry to support the walls of the trench.

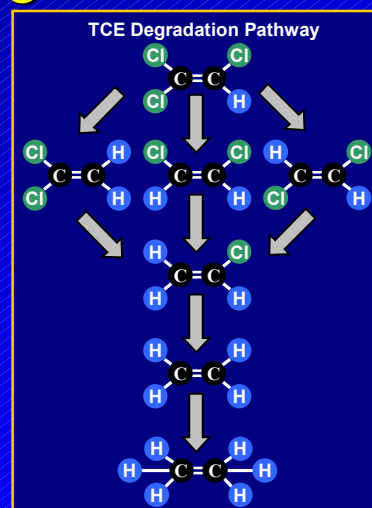
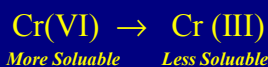
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## Case Study – USCG Station Elizabeth City, NC

- ◆ Influent contaminants
  - [TCE] ~ 4 ppm
  - [Cr(VI)] ~ 10 ppm
- ◆ Zero valent iron backfill
  - TCE removal via abiotic reductive dechlorination (Irreversible)
  - Cr(VI) removal via chemical precipitation (Potentially reversible)

### Cr(VI) Removal Pathway





## Elizabeth City - Specifications

- ◆ Installed in June 1996
- ◆ Continuous PRB
  - Hanging PRB
  - 150 ft length
  - 2 ft flow-through thickness
  - 100% Iron
  - 26 ft total depth
  - 18 ft saturated depth
- ◆ Groundwater velocity
  - 0.5 ft/day



Photo courtesy of ETI

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## Elizabeth City - Alignment

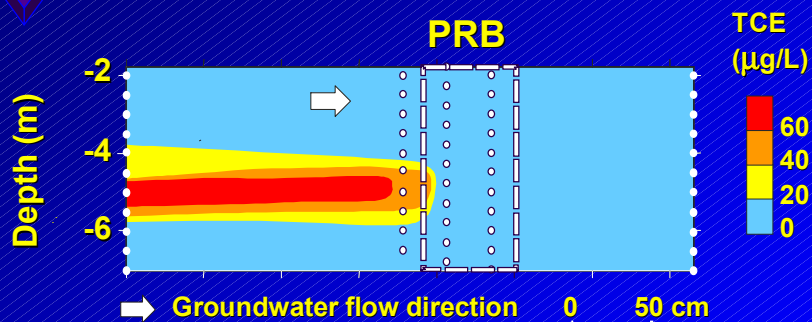


Source: University of Waterloo  
Slide courtesy of ETI

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## Elizabeth City – TCE Profile



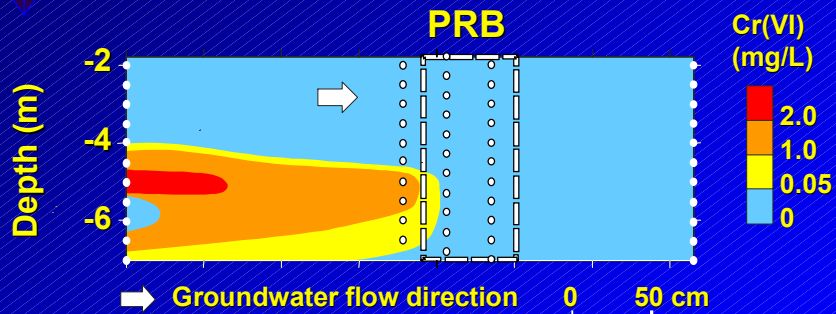
TCE in Transect 1 (after 2.5 years)

Source: EPA/600/R-99/095b, Blowes et al. (1999)  
Slide courtesy of ETI

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## Elizabeth City – Cr(VI) Profile



Cr(VI) in Transect 1 (after 2.5 years)

Source: EPA/600/R-99/095b, Blowes et al. (1999)  
Slide courtesy of ETI

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## *Summary*

- ◆ PRBs may offer a cost-effective method for in situ groundwater treatment through reduced O&M costs;
- ◆ Various reactive media are available with selection based on contaminants of concern and existing/desired groundwater redox condition; and
- ◆ Installation technique for reactive media in situ placement depends on site's physical constraints, plume dimensions, and geology.

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*Thank you.*

*Questions?*

**Steve Brauner, Ph.D.**

PARSONS

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**Fax 781-401-2575**

[steve.brauner@parsons.com](mailto:steve.brauner@parsons.com)

## Overview of Granular Iron PRBs for VOC Treatment

*Michael L. Duchene  
Senior Engineer  
EnviroMetal Technologies Inc.*



## Chlorinated Organic Degradation Using Granular Iron PRBs

- Developed and patented by the University of Waterloo
- Commercialized through EnviroMetal Technologies Inc.
- Over 75 field-scale installations
- First full-scale application completed February 1995
- Sites in North America, Europe, Australia and Japan

envirometal technologies inc.

## Advantages

### Passive, Simple Process

- degrades a wide range of chlorinated organics
- contaminants destroyed
- nontoxic end products
- no energy or equipment
- conserves water
- allows productive use of site

*"The most intriguing idea that has emerged in the remediation field."*

—Lynn Roberts, Ph.D.

The Johns Hopkins University

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## Granular Iron



Grain size: -8 to +50 mesh

Bulk density: 150 lb/ft<sup>3</sup>

Surface area: ~ 1.0 m<sup>2</sup>/g

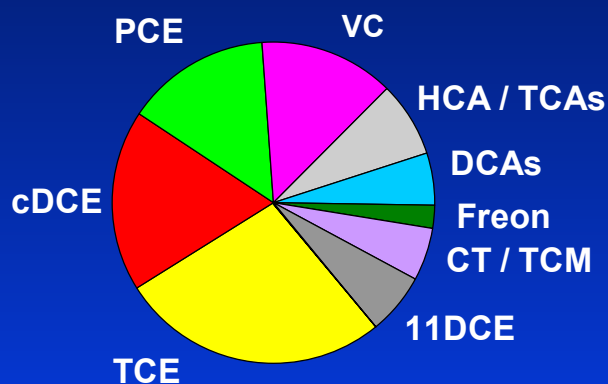
Hydraulic conductivity:

5 x 10<sup>-2</sup> cm/sec (142 ft/day)

Cost: ~ \$350 ton + shipping

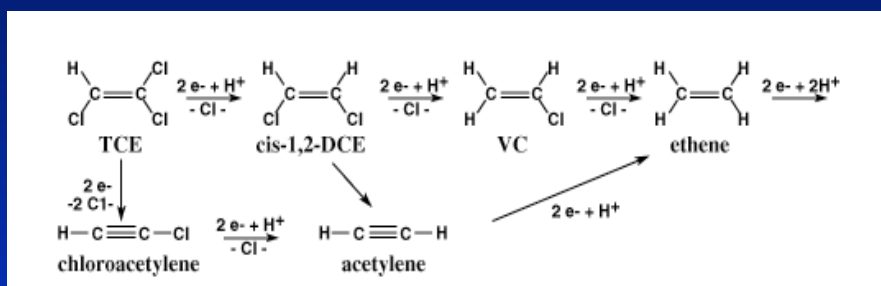
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## VOCs Treated in Iron PRBs



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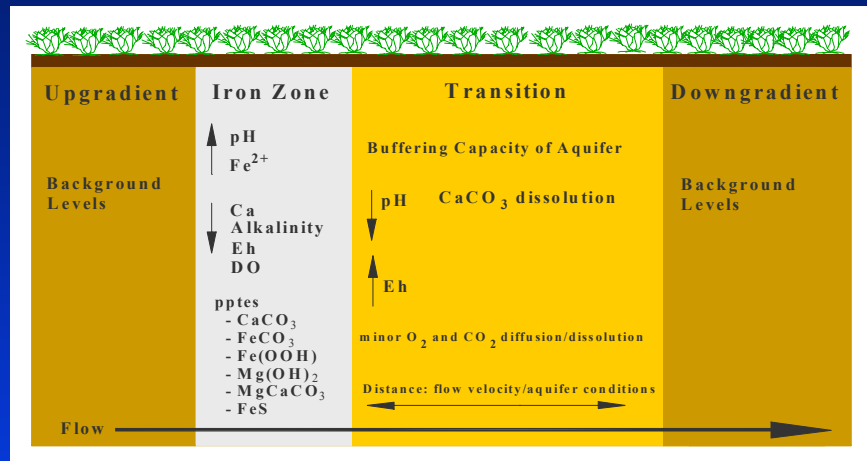
## Degradation Process



- Reaction is abiotic reductive dehalogenation
- Reaction occurs on surface of iron
- Prominent pathway is the Beta-elimination pathway (through chloroacetylene and acetylene)

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## Inorganic Chemistry



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## Precipitate Formation and Effect

- carbonate precipitates begin at upgradient interface
- long-term laboratory simulations indicate precipitate formation over several years cause some permeability loss and significant reactivity loss
- no evidence of hydraulic / reactivity losses in the field over 7 years of operating record

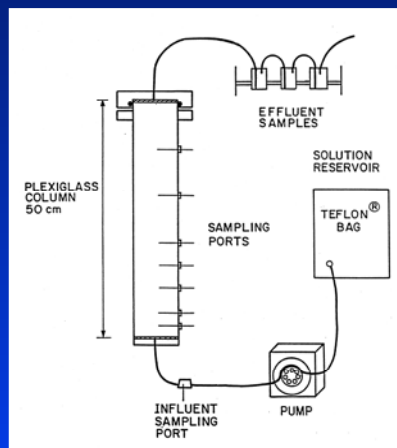
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## PRB Implementation – ETI Involvement

1. **Cost Estimate**
2. **Site Data Assessment**
3. **Bench-Scale Test / ETI Database**
4. **Design / Costing / Construction**  
 site license fee provides use of patented technology at a site
5. **Long-Term Performance Monitoring**

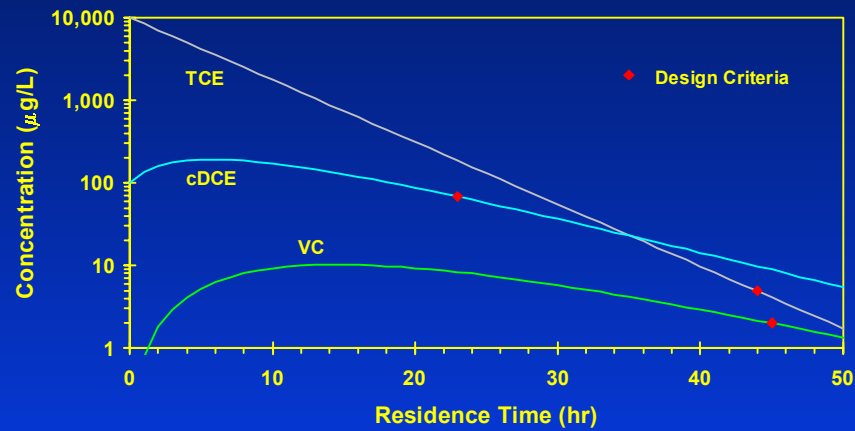
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## Column Treatability Study



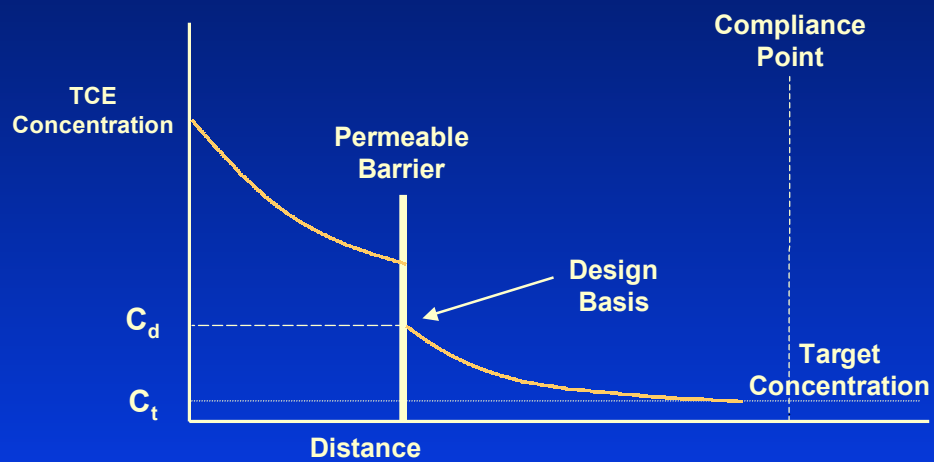
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## Residence Time Requirement



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## Combining PRBs with Natural Biodegradation Processes



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## Treatment Zone Dimensions

**Iron Thickness = Residence time (RT) required X**

**Flow Velocity (FV) through treatment zone**

**Iron Volume = Thickness x Width x Sat. Depth**

**Safety factor / probabilistic design ?**

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## Design Considerations

- groundwater velocity
- plume dimensions – width, depth, saturated depth
- residence time requirement - PRB flow through width
- geology
- installation method

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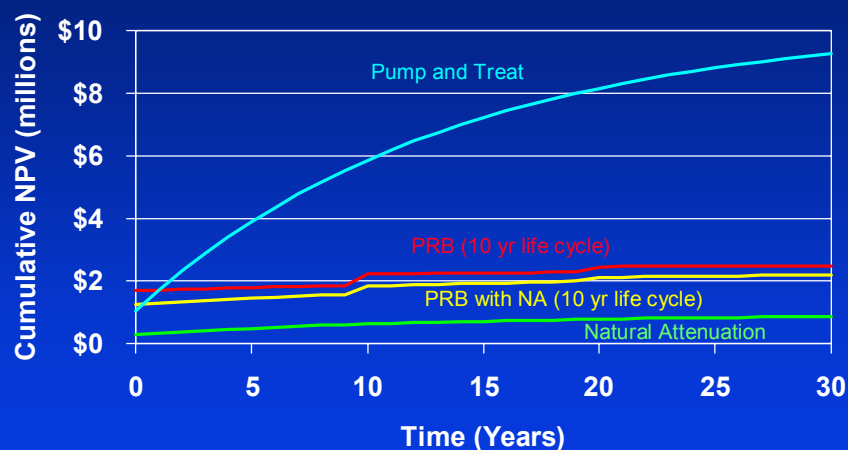
## Treatment Cost - 1999 Installations

	<u>Construction</u>	<u>Iron</u>	<u>Total</u>
<b>Backhoe Construction, OH</b>			
• 8 ppm TCE			
• 20 ft deep, 200 ft long	\$36,000	\$28,000	\$64,000
<b>BioPolymer Trench, NH</b>			
• 10 ppm cDCE; 5 ppm TCE; 1 ppm VC			
• 33 ft deep, 150 ft long	\$200,000	\$130,000	\$330,000
<b>Trench Box, WY</b>			
• 21 ppm TCE; <1000's ppb cDCE, VC			
• 23 ft deep, 565 ft long	\$255,000	\$745,000	\$1,000,000

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## Cost Comparison

TCE Plume (10 mg/L), 400 ft wide, 80 ft deep



Source: DuPont 2000

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## Full-Scale System Construction

### 35 Continuous Reactive Walls

- biopolymer (11)
- cofferdam (8)
- continuous trencher (6)
- hydrofracturing (3)
- supported excavation (3)
- open trench (2)
- trench box (1)
- jetting (1)

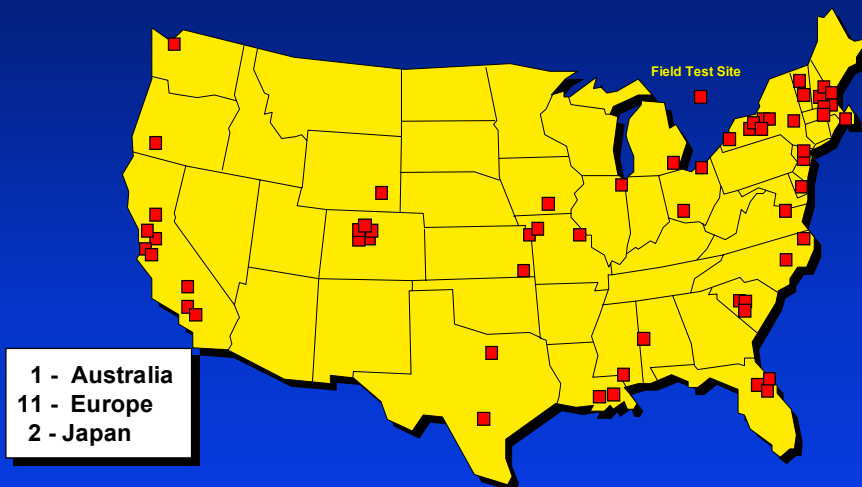
### 12 Funnel and Gate Systems

- slurry wall (6)
- sheet piling (4)
- HDPE (2)

### 3 In-situ Reactive Vessels

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## United States Field Installations



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## Needham, MA



### Continuous PRB

- Installed June/July 2001
- 510 ft total length
- 2 zones - 0.5 ft / 1.7 ft
- 31 ft average saturated depth
- 57 ft maximum depth

### Groundwater Flow Velocity:

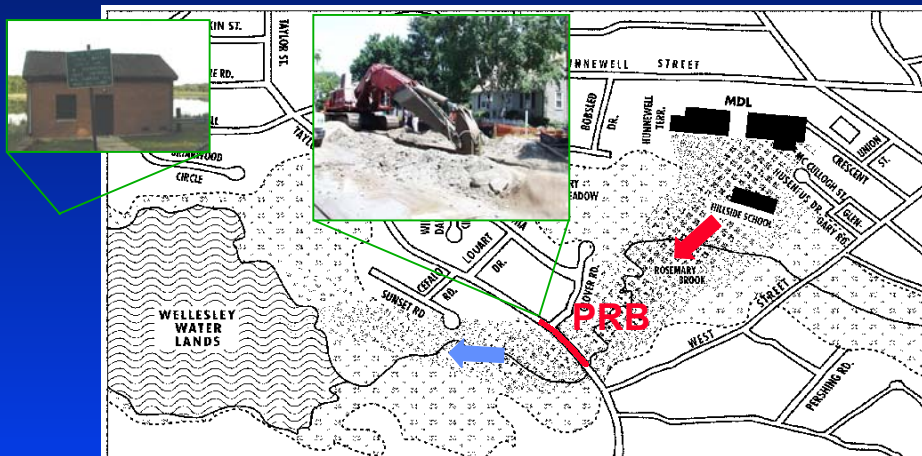
- 3.1 ft/day (design)

### Influent Groundwater:

- 81 ppb TCE (design)

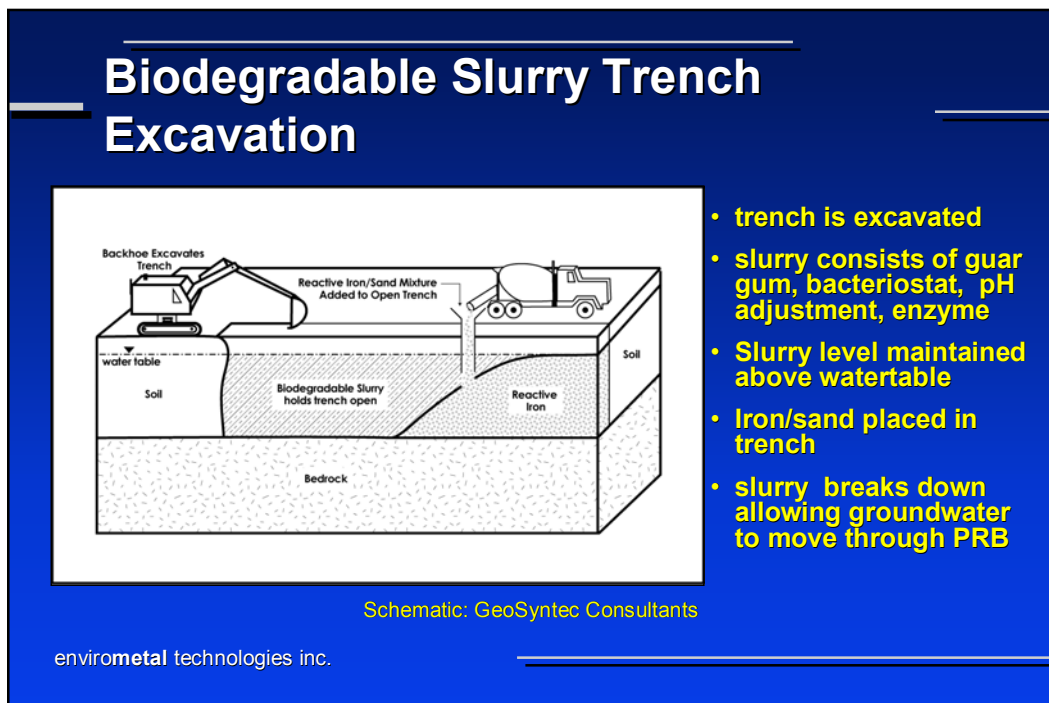
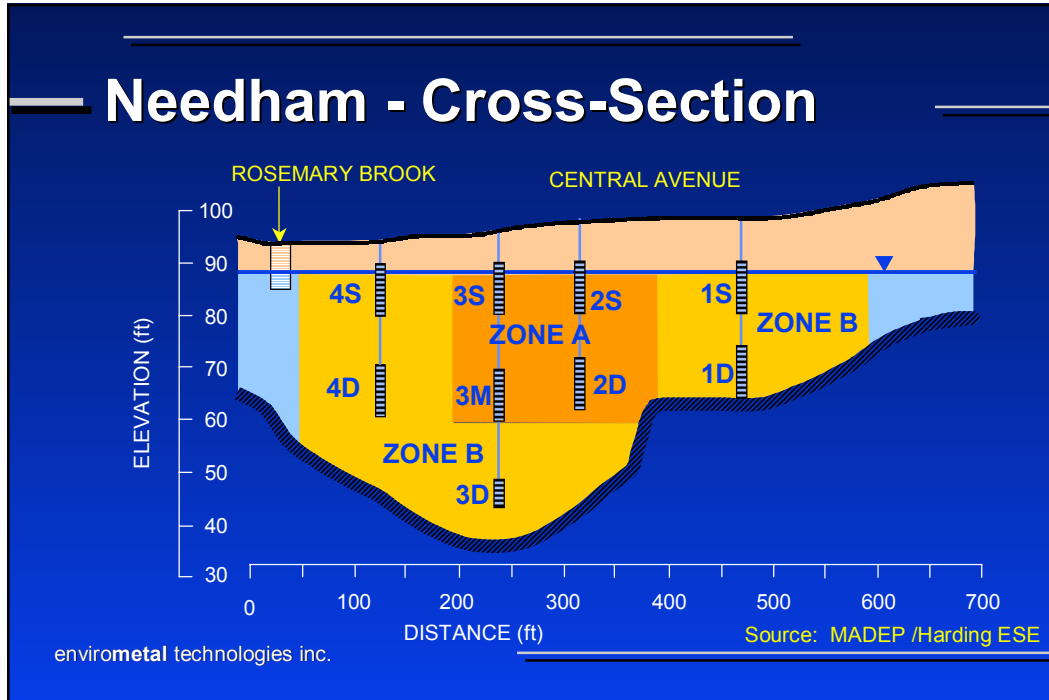
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## Needham, MA



Source: MADEP /Harding ESE

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## Warren AFB, WY



### *Continuous PRB*

- Installed Oct 1999
  - 568 ft total length
  - 3 segments
  - 4 ft / 1 ft / 1.5 ft of iron
  - 15 ft saturated depth
  - Hanging PRB
- Groundwater Flow Velocity:*
- 1.3 ft/day
- Influent Groundwater:*
- 25 ppm total VOCs

Source: AFCEE / URS Corporation, 2001

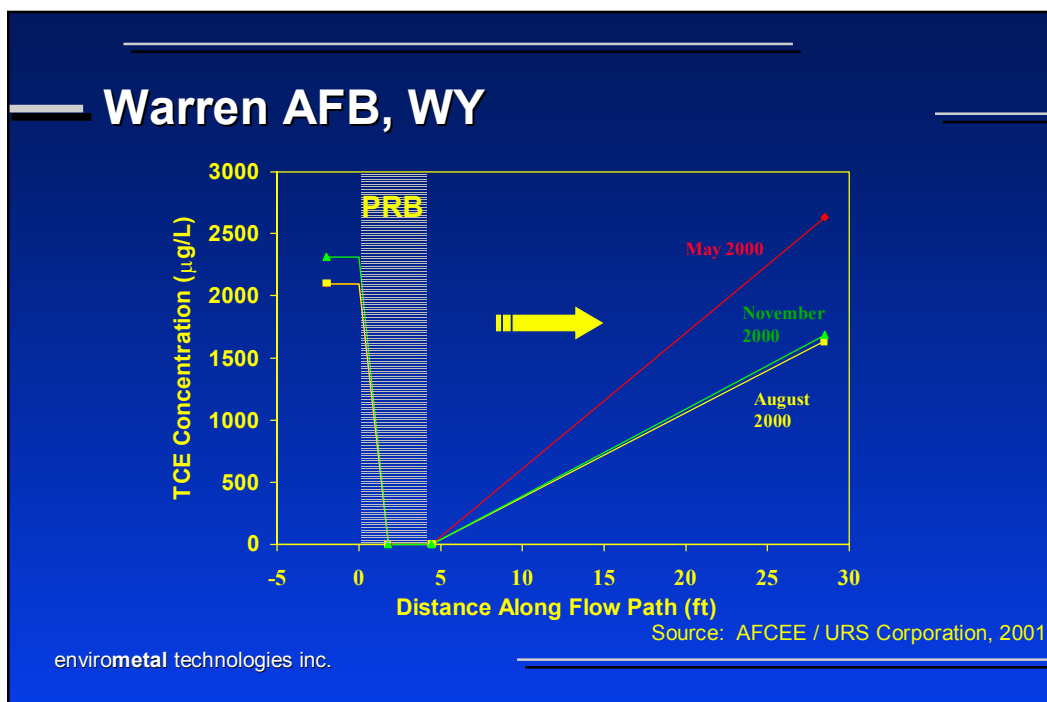
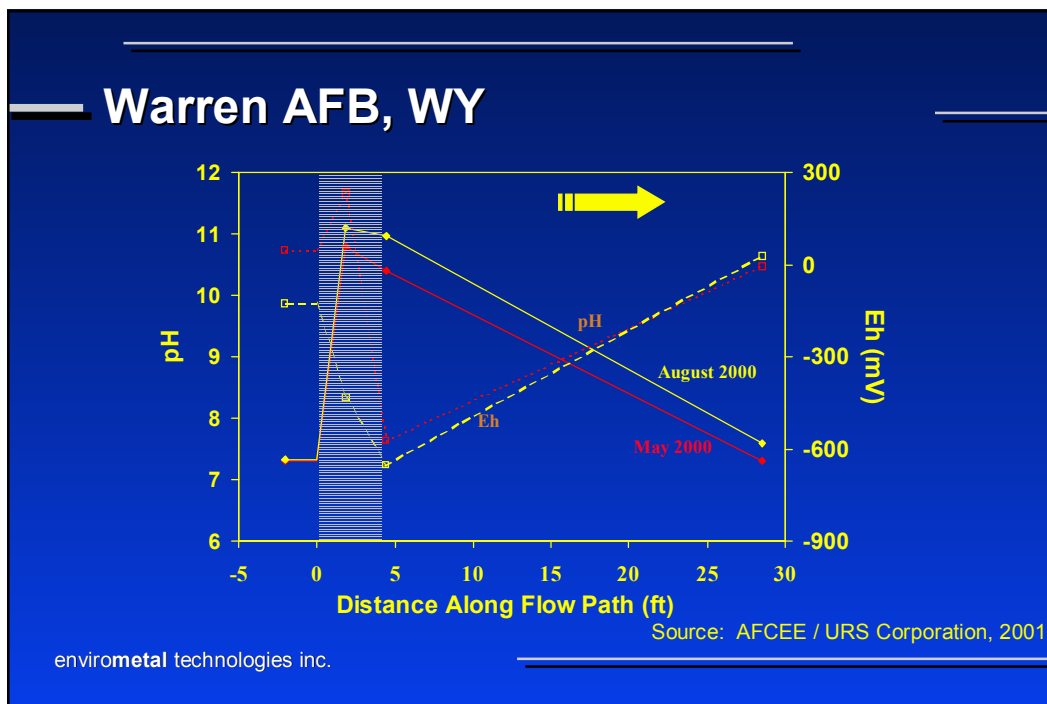
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## Trench Box Construction



AFCEE, URS, Montgomery Watson, 2000

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## Unsupported Excavation



- Trench excavated without support
- Formation does not collapse
- Iron or iron sand mix placed directly into excavation
- Inexpensive construction
- Limited to shallow depths

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## Vertical Hydraulic Fracturing, Iowa



### *Continuous PRB*

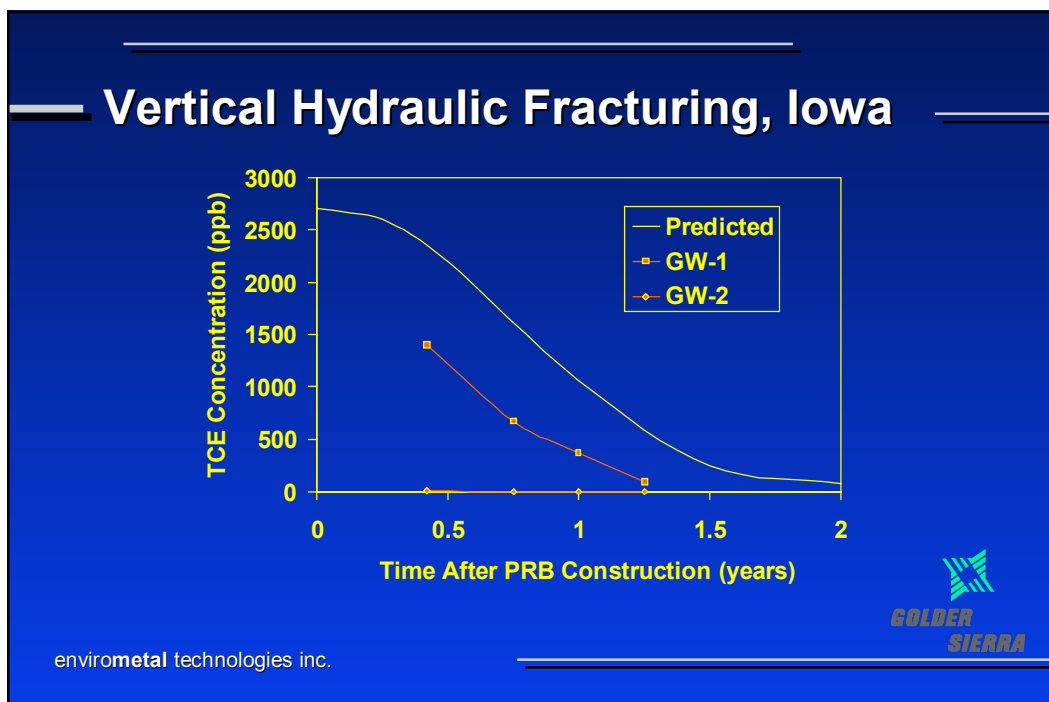
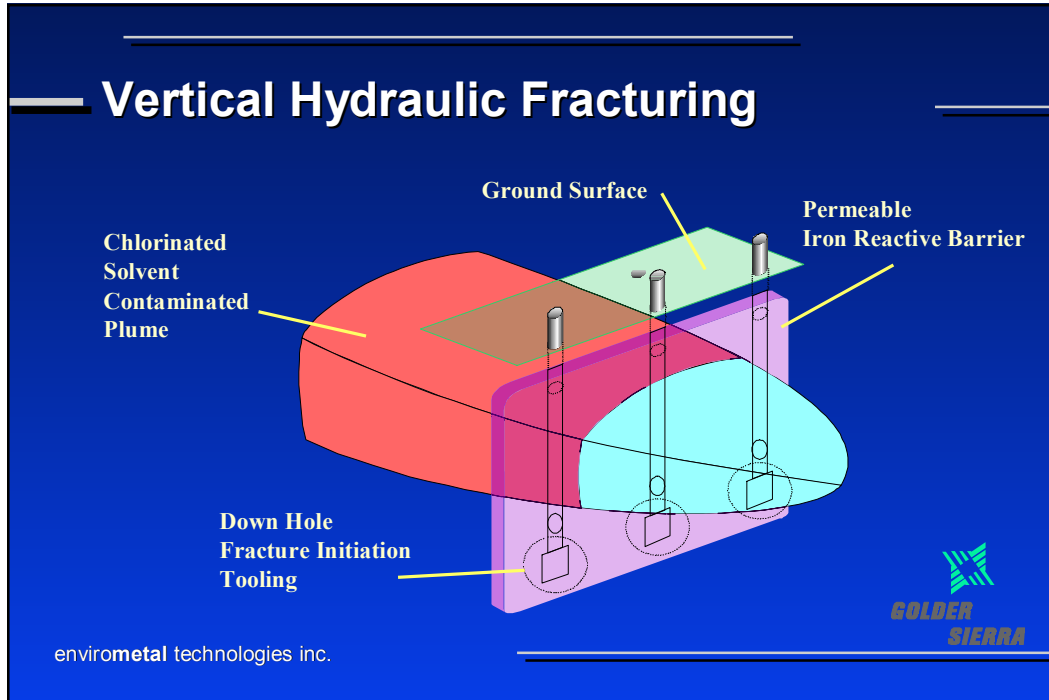
- Installed Nov 1999
- 240 ft total length
- 3-inches thick
- Installed 25 ft to maximum 75 ft bgs

### *Influent Groundwater:*

- 3 mg/L TCE

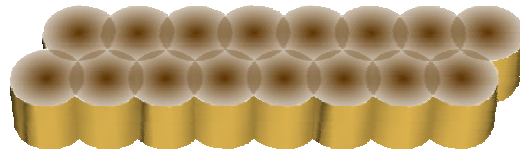


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## Jetting Geometries

**Columnar:**



**Diaphragm:**



**Dual Diaphragm:**



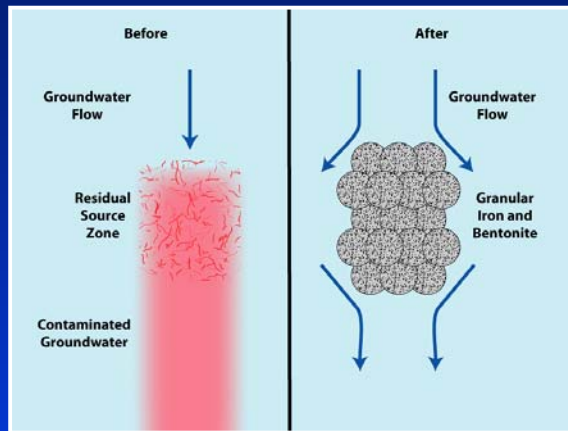
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## Installation In Fractured Bedrock

- **Refractive flow and treatment**
  - discrete blasting creating high K zones
  - in-situ treatment zone
- **Pneumatic fracturing and injection**
- **Blasting and excavation**
- **Array of boreholes**
- **Permeation grouting ( fracture infilling )**
- **Pump-and-treat with above-ground system**

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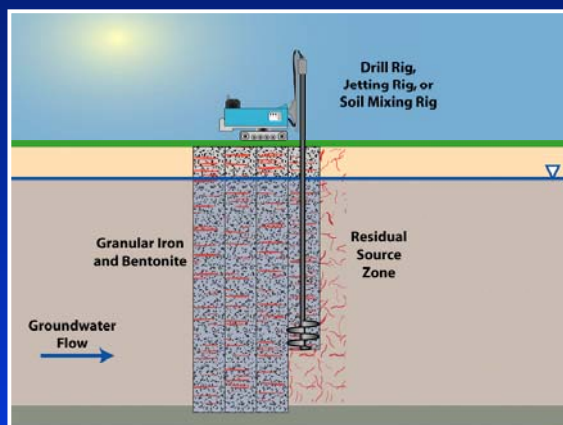
## Treating DNAPL Source Zone



- **Reduced permeability results in:**
  - long residence time for DNAPL dissolution and degradation by iron
  - low VOC mass flux out of source zone

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## Treating DNAPL Source Zone



- **Iron and clay (bentonite/kaolinite) mixed into source zone**

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## Long-term PRB Performance

- consistent performance with respect to VOC degradation rates
- greater than 7 year track record
- no evidence of microbial fouling under flowing conditions
- precipitate formation will influence long-term performance

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## Hydraulic Performance Issues

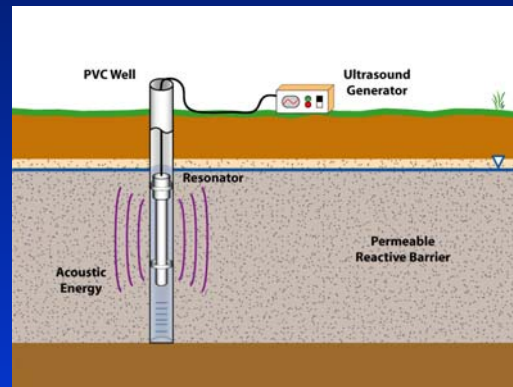
- Hydraulic by-pass of contaminants due to:
  - incomplete plume capture
  - change in seasonal flow direction
  - underflow or overflow
  - Permeability reduction due to construction
- Reduced residence time due to flow velocity variation along line of installation

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## PRB Operations and Maintenance

- Ultrasound
- Hydraulic pressure pulsing
- Replacement

Lump sum should be budgeted into O&M every 10 years



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## Sources of Information

- [www.rtdf.org](http://www.rtdf.org)
- [www.eti.ca](http://www.eti.ca)
- [cgr.es.eogi.edu/iron](http://cgr.es.eogi.edu/iron)
- [www.itrcweb.org](http://www.itrcweb.org)
- [www.prb-net.org](http://www.prb-net.org)
- [www.epa.gov/tio](http://www.epa.gov/tio)

envirometal technologies inc.

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envirometal technologies inc.

## Zero Valence Iron Injection for Source Treatment



- *“An Advanced Solution for In-situ Chemical Reduction ”*
- *Presented by John Liskowitz*
- *President - ARS Technologies Inc.*

## Effective In Situ Chemical Reduction Using ZVI Injection Is Dictated by Four Elements

**Selection of Material** which provides treatment performance, cost effectiveness and no hazardous effect.

**Contact** between the injected ZVI and the target compound

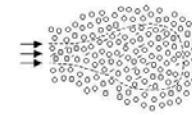
**Quantity** of ZVI Powder injected in the subsurface

**Uniformity** of injected ZVI to mirror target contaminant distribution

## Mechanism(s) of ZVI Injection

### Mechanism 1: Fluidization of Geologic Matrix

-Typical in Sand/Gravel Media



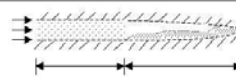
### Mechanism 2: Fluidization w/some discrete channelization

-Typical in Sands/Silts/Minor Clay



### Mechanism 3: Discrete Channelization/Fracture Emplacements

-Typical in Clays/Fracture Rock Media



## Gas Atomized Injection Used to Emplace Iron



Hydraulic Pumping



Liquid Atomization

## Overview - Ferox<sup>SM</sup> Process

### Ferox<sup>SM</sup> Process

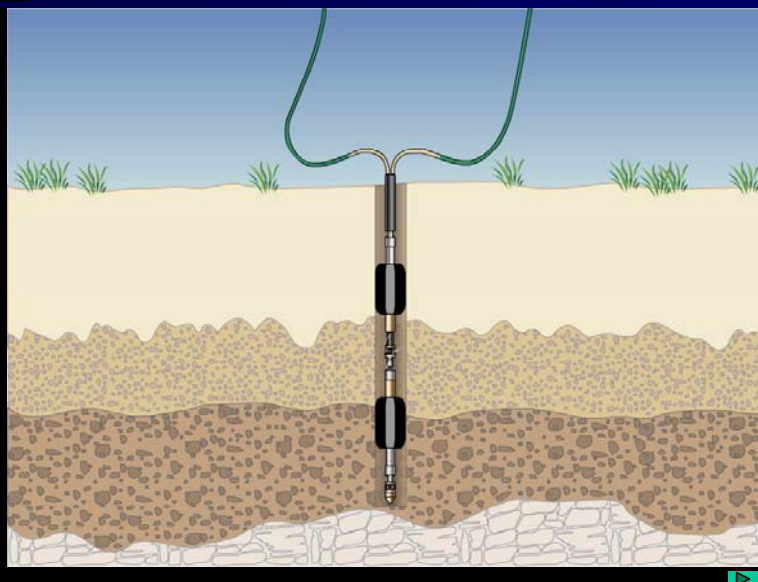
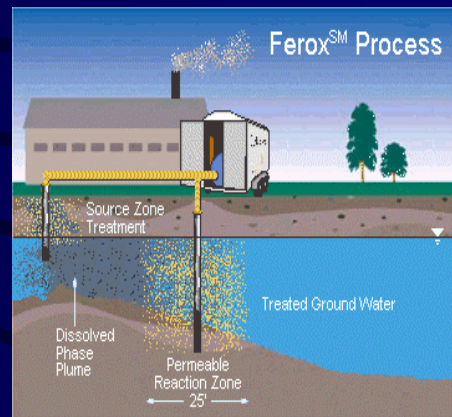
U.S. Patent # 5975798 November 1999:

*Capable of treating dissolved phase and source contamination*

*Injections possible underneath existing structures/utilities*

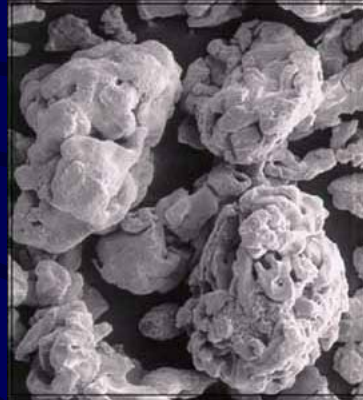
*Not limited by depth of application*

*Iron powder dosage emplaced to mimic in-situ contaminant concentration*



## **Ferox<sup>SM</sup> Material is a Highly Reactive Pure Iron Powder**

- Irregular Shape Provides Maximum Surface Area
- **FDA Certified 95+% Pure**
- Trace Carbon - Provides Enhanced Reaction Benefits
- 40-80 um size particles
- Cost \$1.45 - 1.70/lb



## **Current Technology Status**

- 22 laboratory treatability tests completed
- 12 field systems completed
  - Largest 45,000 square feet**
  - Deepest 110 feet**
- 6 systems currently being installed

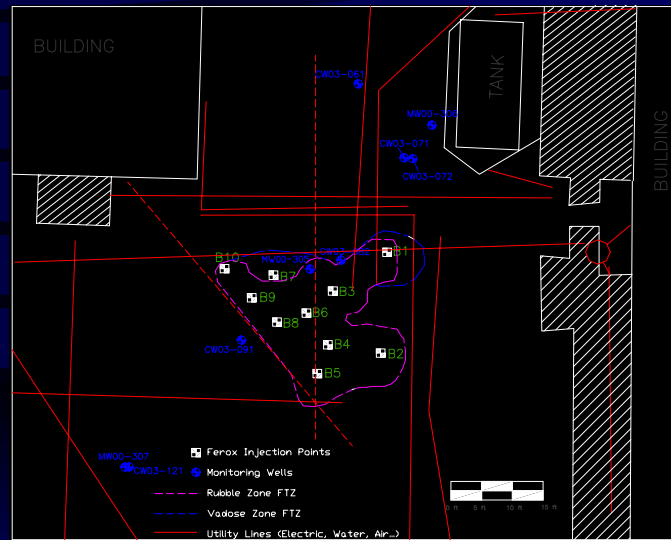
## Application Equipment -



## Application - Ferox<sup>SM</sup> Pre Injection Conditions at Site



## Application at Industrial Site



## Application - Ferrox<sup>SM</sup> Injections



## **Case Study #1 Fractured Bedrock Aquifer**

NJ ISRA Site, Central New Jersey

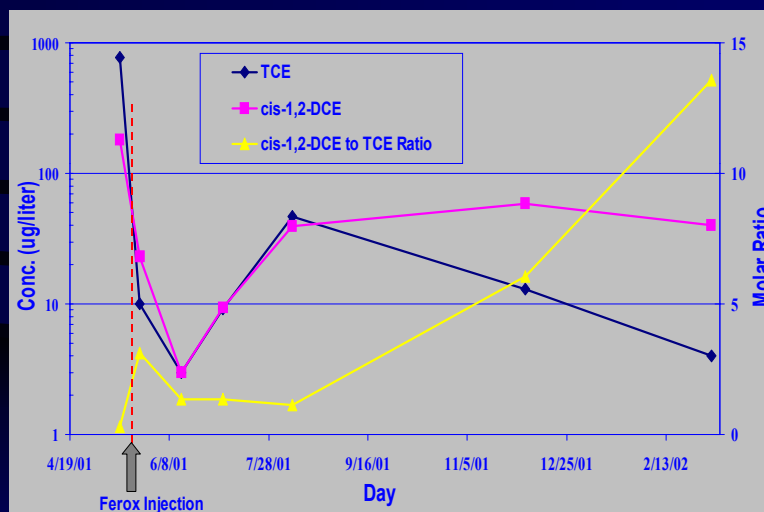
### **Site Background**

- Historic discharge of TCE into a weathered shale/siltstone formation
- Dual-Phase Extraction (DPE) enhanced by Pneumatic Fracturing installed and operated 1995-2001
- In six years = ~400 lbs of VOC from site
- TCE reduced from 170,000 ug/L to less than 3,000 ug/L in Source Area
- but....Mass Removal Rate of DPE went asymptotic

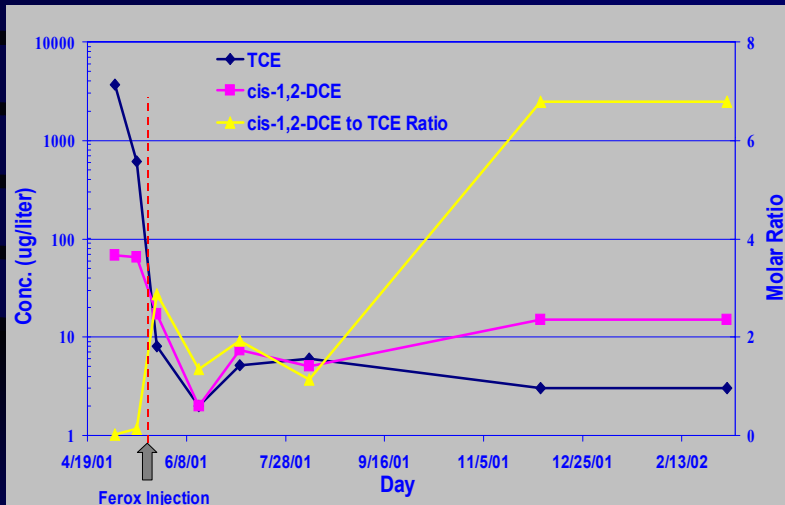
A map of the Ferox plume area. The map shows several monitoring wells (MW-2, MW-3S, MW-5S, MW-6, MW-3S) and performance monitoring wells (PF-2A, PF-4A, PF-7A, PF-9A). Ferox injection locations are marked with red star symbols. A legend indicates that red stars represent Ferox injection locations and pink stars represent performance monitoring wells. A scale bar shows a distance of 80 feet. An arrow indicates the groundwater flow direction towards the bottom right.



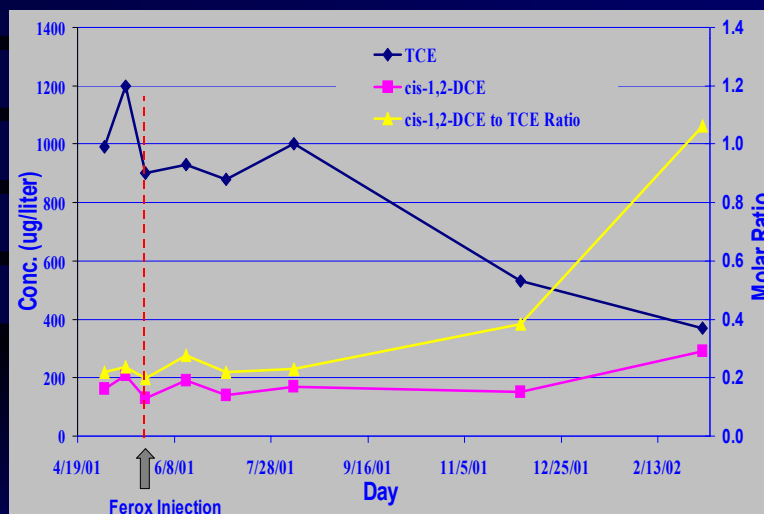
## Concentrations vs. Time PF-7A (Injection Point)



## Concentrations vs. Time MW-2 (Injection Area)



## TCE Concentration vs. Time MW-5S (Side-gradient)



## pH Effects

Ferox Injections

Well ID	pH (SU)							
	5/3/01	5/14/01	5/24/01	6/14/01	7/5/01	8/9/01	12/4/01	3/8/02
MW-2	7.42	7.46	9.56	8.60	9.17	10.03	9.22	9.24
MW-3S	7.83	7.68	8.05	7.69	7.67	7.77	7.85	7.93
MW-5S	7.57	7.50	7.77	7.90	7.68	7.87	7.60	8.04
MW-6	8.15	8.06	8.18	8.22	8.07	8.10	8.02	7.93
PF-2A	7.22	6.87	7.55	7.68	7.54	7.38	7.52	6.59
PF-4A	7.57	7.25	9.25	9.08	8.73	9.16	7.45	8.24
PF-7A	NS	6.62	9.22	8.20	6.95	8.91	9.12	8.25

## Dissolved Oxygen Effects

Ferox Injections

Well ID	DO (mg/l)							
	5/3/01	5/14/01	5/24/01	6/14/01	7/5/01	8/9/01	12/4/01	3/8/02
MW-2	6.42	5.35	0.00	0.00	0.00	1.76	0.00	0.00
MW-3S	0.56	1.36	0.28	0.00	0.00	2.23	0.00	0.00
MW-5S	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00
MW-6	10.49	8.56	1.20	0.00	0.00	0.00	0.71	0.00
PF-2A	7.08	5.29	1.61	0.00	0.00	0.00	0.00	0.77
PF-4A	1.08	0.22	0.00	0.00	0.00	0.00	0.00	0.00
PF-7A	NS	4.56	0.00	0.00	0.00	2.23	0.00	0.00

## Redox Potential Effects

Ferox Injections

Well ID	ORP (mv)							
	5/3/01	5/14/01	5/24/01	6/14/01	7/5/01	8/9/01	12/4/01	3/8/02
MW-2	125	128	-542	-496	-403	-715	-314	-212
MW-3S	268	109	165	5	65	-62	80	95
MW-5S	248	108	-257	-26	49	-66	-78	-66
MW-6	280	116	-126	114	103	6	71	0
PF-2A	156	192	-162	-362	-215	-211	-144	95
PF-4A	120	136	-659	-533	-535	-335	-190	-251
PF-7A	NS	178	-580	-537	-449	-483	-359	-281

## Project Summary and Future Status

- Ferox<sup>SM</sup> treating residual TCE not addressed by SVE/P&T system
- RAW Submitted proposing expansion of pilot-test zone injections in 2003
- Application cost \$5 -\$8 per pound of iron Emplaced

## Summary of Results

- TCE Reduced by up to 99%
- No rebound observed in most wells 10 months after injections
- Geochemical parameters responded to ZVI as expected:
  - DO decreased to zero in nearly all wells
  - pH increased by 0.2 to 1.8 s.u.
  - ORP decreased significantly in all wells by 79 to 459 mv
- Injection pressure less than 120 psi.
- Injection pressure influence generally uniform in all directions

## Case Study #2- NASA's MSFC Source Area 2 Huntsville, Alabama

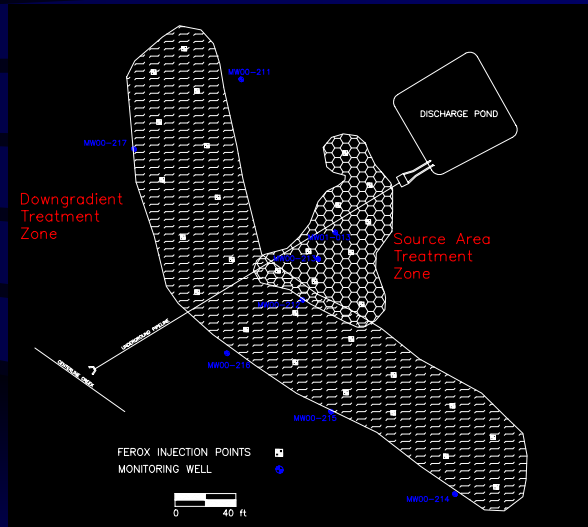
## Source Area 2 Site Background and History

- Located adjacent to former Rocket Test Stand
- Holding Pond Used for Coolant Water Believed Source of TCE
- Impacted Area along sewer line originating from Holding Pond
- TCE source area and groundwater plume
- Presence of UXO prevented digging at surface
- Industrial sewer, high pressure gas line present in area

## Source Area 2 - Soil Cores



## Source Area 2 - Case Study



## Source Area 2 - Field View



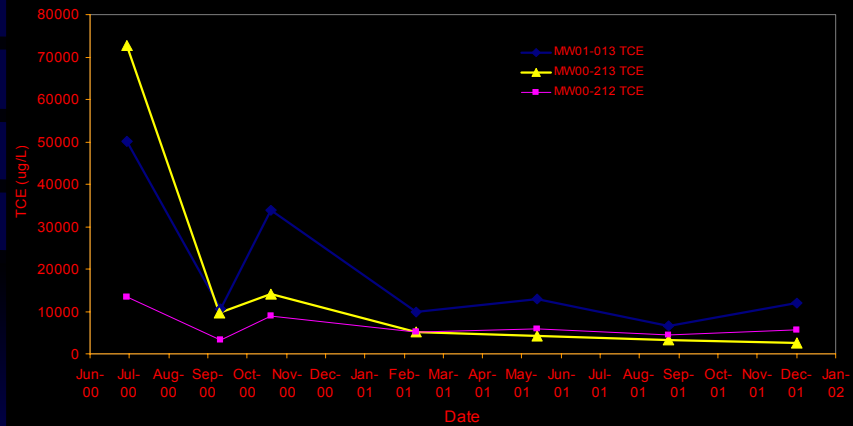
## Injection Event



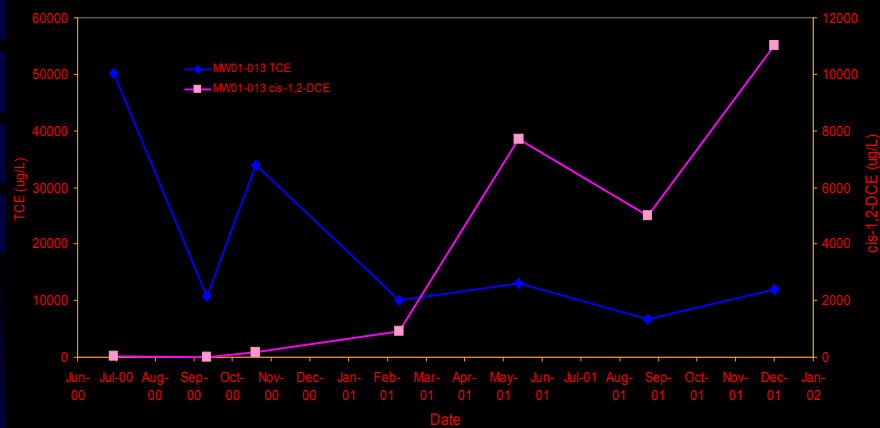
## Soil Sampling - Ferox<sup>SM</sup> M Injection Zone and Background Cores



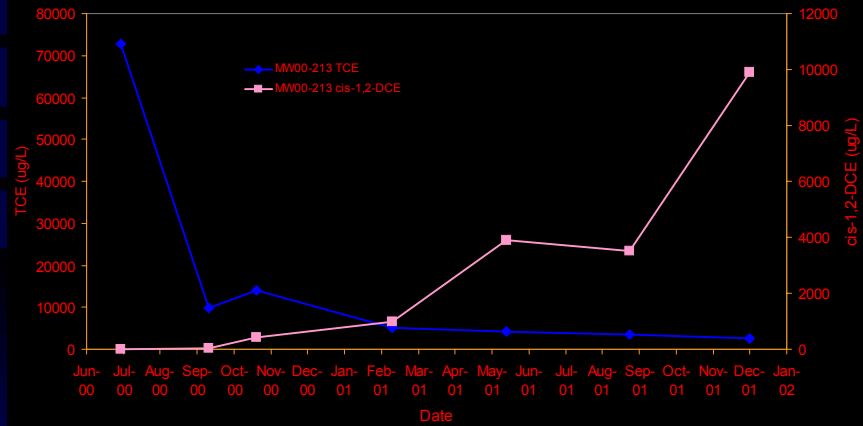
# **Ferox<sup>SM</sup> Post-Injection GW Sampling SA-2** **TCE Concentrations** (Source Area Wells)



# **Ferox<sup>SM</sup> Post Injection GW Sampling SA-2** **TCE and cis-1,2-DCE vs. Time** (MW01-013)



## Ferox<sup>SM</sup> Post Injection GW Sampling SA-2 TCE and cis-1,2-DCE (MW00-213)



## Chloride Mass Balance Within 97 %

Station ID	Observed	Observed	Observed
	TCE Reduction (mg/l)	Chloride Production (mg/l)	DCE Production (mg/l)
MW01-013	26.2	16.2	4.9
MW00-211	0.0	2.9	0.0
MW00-212	6.1	5.6	0.5
MW00-213	65.2	36.7	8.0
MW00-214	0.0	0.1	0.0
MW00-215	0.0	0.7	0.0
MW00-216	-0.1	2.3	-0.1
MW00-217	0.0	2.6	0.0
<b>Total (mg/l)</b>	<b>97.4</b>	<b>67.1</b>	<b>13.3</b>
<b>Total (mmol/l)</b>	<b>0.74</b>	<b>1.89</b>	<b>0.14</b>

Total TCE Reduced Due to Chloride and DCE Production- 0.72 mmol/l  
Mass balance closes within about 97 %

## Project Summary

- 20,000 lbs of Ferox Material Injected
- Target Depths to 37 feet
- Gas and Slurry Injected 60+ feet Using
- Pressures ranging from 60 to 120 psi
- Projected Cost For Field Application  
\$17/Pound Iron Injected

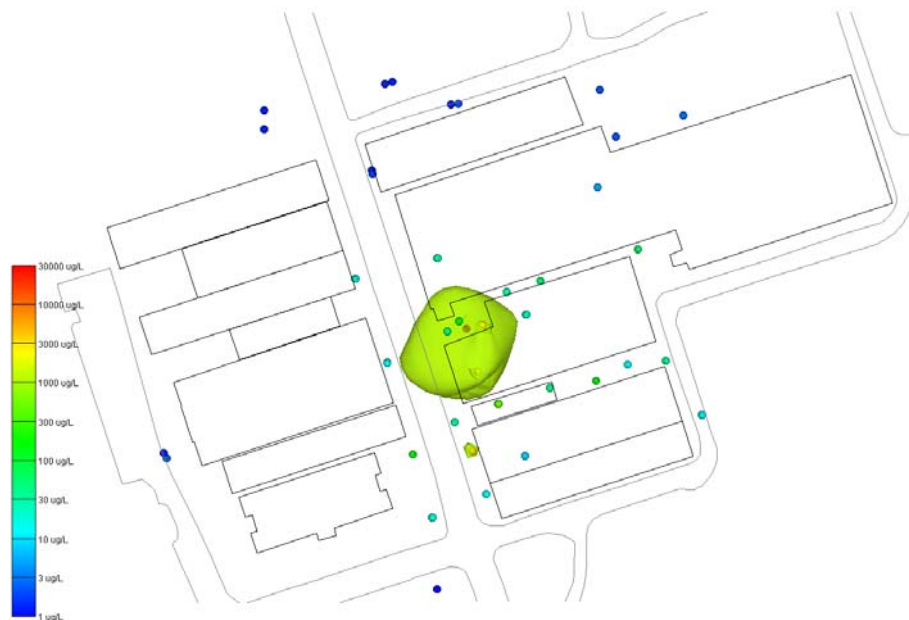
## Cr+6 Source Reduction DOD Facility, Charleston SC



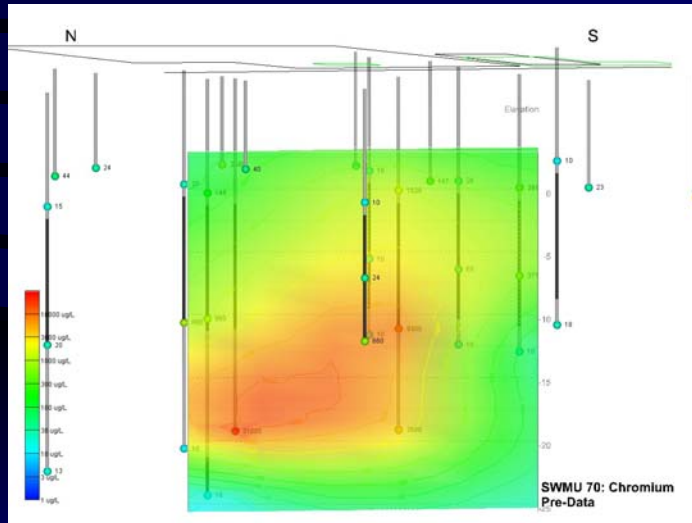
## Site Background

- Plating Shop, source of Cr+6 in groundwater
- Electrical Vault and Corridor under building flooded with high levels of Cr+6 solution
- Previous Treatment Include removal of old plating shop, contaminated soil, contaminated water in vault, and vault
- Geology Consists of fine sands and sandy silts interbedded with sand to confining unit
- Thin plastic clay stringers also present

Plan View: Pre-Injection Chromium Concentrations >1000 ug/L



## Cr<sup>6+</sup> Pre-Treatment Profile View - Cross Section



## How Safe Injections Were Applied Under Building

- Thorough review of structural drawings and utility maps
- Computer Modeling to Assess Movement Cause and Effect Loads
- Documentation of Pre-existing Condition
- Develop Site Empirical Data Prior to injecting within Building.

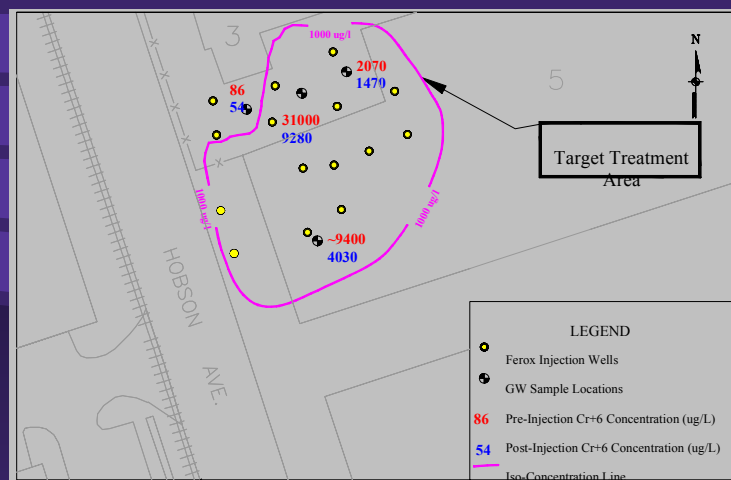
Injection Approach Under Building  
Required Modeling and Documentation of  
Existing Condition



## Project Summary

- Injections completed January 2002
- Minimal disruption to tenant activities in building (no lost time for tenant)
- 37,000 lb ZVI injected
- Post-treatment GW sampling monitoring Cr+6 and GeoChemical Parameters

## Post Injection Results After 6 Months



## GW Geo-chemical Parameters (Initial 5 Months)

	Ferox Injection			Ferox Injection			Ferox Injection			Ferox Injection		

## Interesting Observations

- ⇒ GW Geo-Chem. Data shows Delayed Effect  
Microfilm Coating on Iron Particles?  
(Reference Farrell et. al ES&T 2001)
- ⇒ Measurement of Hydrogen (Microseeps) good  
parameter to monitor (14 to 29,000 nM increase in  
Center of Source Area)
- ⇒ Total Cr measurement in ground water decreasing.  
(Migration or Sampling Method Issues???)

## Ferox<sup>sm</sup> Applications in New Jersey

<u>Site Desc.</u>	<u>Type</u>	<u>Scope</u>	<u>Status</u>	<u>Cost Factor</u>	<u>Results</u>
1999 ISRA Site Passaic County, NJ	Pilot Test CVOC's	150 ft by 20 ft 4,400 lbs Fe	2.0+ years	\$35 /lb injected	Iron May be 90% TCE Reduction Prior to Rebound
2000 DOD Site Northwest NJ	Pilot Test Cell  VC, Cis- DCE	30 by 60 feet  10,000 lbs Fe	2.0 years	\$15/lb injected	Downgradient VC reduced 85%, Cis- DCE 94% Inside Reaction Zone 100%
2001 ISRA Site Fractured Bedrock  Central N.J.	Pilot Test  CVOC's	100 by 40 ft. 4,000 lbs Fe	1.0 Year	\$6 / lb injected	95% + Reduction within Treatment Zone  GW Geochem Changed
2002 Burnt Fly Bog, Marlboro NJ	Lab. BenchScale PCB's and Pb	N/A	Draft Report Sub. to EPA	N/A	Complete Pb reduction, PCB Partial Reduction

THE END

- [www.arstechnologies.com](http://www.arstechnologies.com)
- [www.ifracture.net](http://www.ifracture.net)